The Western Australia Astrobiology Grand Tour

Australian Centre for Astrobiology (ACA) & the University of New South Wales (UNSW)

NASA Astrobiology Institute Field Trip Scholarship Recipients:
Giada Arney, Marisol Juarez Rivera, Shaunna Morrison

Visiting Shark Bay and the Pilbara was an amazing, once-in-a-lifetime experience! We saw, experienced, and learned so much. Our diverse group consisted of graduate students, educators, and early- and late-career scientists from a broad range of backgrounds, including biology, astronomy, geology, and science education, and from widely varying institutions, such as the Australian Centre for Astrobiology (ACA), Smithsonian National Museum of Natural History, Powerhouse Museum of Applied Arts & Sciences, and Universities in Australia, Canada, the UK, and the US.

For Giada, Marisol and Shaunna, this trip was made possible by the NASA Astrobiology Institute (NAI).
Thank you, NASA Astrobiology Institute!

We flew from Perth to Carnarvon and got to see the incredible colors of Shark Bay from the air! The most hypersaline part of the Bay, Hamelin Pool, is bounded to the north by the Faure Sill, a seagrass bank that restricts ocean water exchange. The bay is also quite shallow with an average depth of about 10 m. The restricted connection to the ocean and rapid rate of evaporation has caused Hamelin Pool to have hypersaline waters (about twice the salinity of normal seawater) that are also highly alkaline. This unique environment means that the range of organisms able to tolerate these conditions is limited, allowing the bacterial mats that make up the stromatolites to thrive without being feasted upon!

Stromatolites, Carbla Beach, Shark Bay

The stromatolites were incredible to see! UV-screening, dark-colored pigment, scytonemin, is synthesized by certain types of cyanobacteria. Darker regions have higher levels of scytonemin. Interestingly, scytonemin provides resistance to UVC, the shortest wavelength UV radiation. UVC is blocked by ozone in the modern atmosphere, but it reached Earth's surface prior to the rise of the ozone layer. Therefore, UVC resistance may the predate oxygen level rise 2.5 billion years ago.

One type of organism that can survive in Hamelin Bay is the *fragum erugatum*, a salt tolerant bivalve mollusc. Entire beaches along the Hamelin Bay shores are made up of their shells, and they are even used in local landscaping.

At the first beach we visited, the bottom of the water was coated in what looked like fragments of tan-colored rocks. However, when picking one up, we discovered they were soft and broke open easily: inside was a colony of microbes! In the above image, Marisol is holding a piece of one of these “rocks”, and the dark microbial interior can be seen. Our guides thought they were pieces of microbial mats that were broken apart by a recent storm. Shark Bay is a constantly changing environment.

Researcher, Teresa Morris, joined us at Shark Bay’s Carbla Beach to discuss her research on the microbial mats living here in this delicate and ever-changing ecosystem.

For a dramatic change of scenery, we toured the Tom Price iron ore mine. The 2.63-2.45 billion year old Mount Tom Price is a banded iron formation (BIF) of the Hamersley Group.

(from left to right) Marisol Juarez Rivera, Bruce Damer, Tara Djokic, Malcolm Walter, and David Deamer Pose with an open pit of the Tom Price Mine.

The Pilbara is incredibly red thanks to the iron in its soil. Iron mining is, unsurprisingly, a significant industry in the area.

The red soil, ancient rocks and dry climate are reminiscent of another field area we'd like to visit: Mars. This is where Shaunna conducts her research – remotely, of course, using the NASA Curiosity Rover. As a member of the CheMin X-ray diffraction instrument team, she examines rock and sediment samples to determine their mineral assemblages and mineral compositions. A rock unit's mineralogy tells the story of how it came to be. Minerals tell us how old something is, what the atmosphere was like during formation, whether or not it's been exposed to liquid water, and much, much more. This information helps answer questions like: Did this planet have the materials from which life emerged? Did it have the chemical components necessary to support lifeforms? Was the atmosphere suitable to living organisms? If so, of what nature (photosynthetic? chemosynthetic?) The rocks and minerals of Western Australia are often analogous to those on Mars. For example, hematite concretions, also known as *blueberries*, are found in both Western Australia and Meridiani Planum, Mars. Studies of blueberries on Earth indicate they form in the presence of liquid water and some results further suggest formation in the presence of microbes. These findings, along with many others gleaned from studying Earth materials, pose interesting questions for Mars researchers, like Shaunna, and give insight into astrobiology, habitability, and the origins of life.

Hematite “blueberries”

Our next major stop was Karijini National Park. Here, beautiful blue pools are surrounded by tall cliffs of brick red banded iron formations of Dales Gorge that date to 2.45 billion years ago. The iron-rich and iron-poor laminations have been suggested to result from seasonal blooms of oxygenic cyanobacteria, altering the oxidation state of the water and allowing iron to precipitate out. Unfortunately, no microfossils have been found in the bands and the metamorphic grade is too high to allow preservation of hydrocarbon biomarkers.

Dales Gorge cuts through the 2.49 Ga Brockman Iron Formation, which is part of the Hamersley group. The Hamersley Group consists of thick successions of BIFs interbedded with shale, carbonates, tuffs, and meteorite ejecta (see below).

Marisol examining the ejecta deposit resulting from a meteorite impact.

One of the most popular features of Dales Gorge is Fortescue Falls - cited as one of the country's most spectacular natural attractions. Despite the chilly temperature, many in our group took a swim here.

Group photo overlooking Dales Gorge - (front, left-to-right) Kim Rehm, Marisol Juarez Rivera, Roy Sach; (middle, left-to-right) Dave Lageson, Emma Stock, Nicola Methieson, Ian Crawford, Doug Erwin, Ray Jaywardhana, Shaunna Morrison, Giada Arney, Isabelle Kingsley; (back, left-to-right) Bruce Damer, David Deamer.

Getting ready for dinner at our campsite in Karijini National Park.

Next up was the 2.7 billion-year-old stromatolites at a site called “Knossos” in the Tumbiana Formation of the Fortescue Group. The stromatolites at this location were abundant and diverse, and the rock record also shows evidence of desiccation cracks and storm events. ΔCorg values as low as -60 per mil have been measured here, which is attributed to organic carbon input from methane cycling metabolisms.

Small Knossos stromatolites can be seen in a top-down view that give us another view of their layered structure.

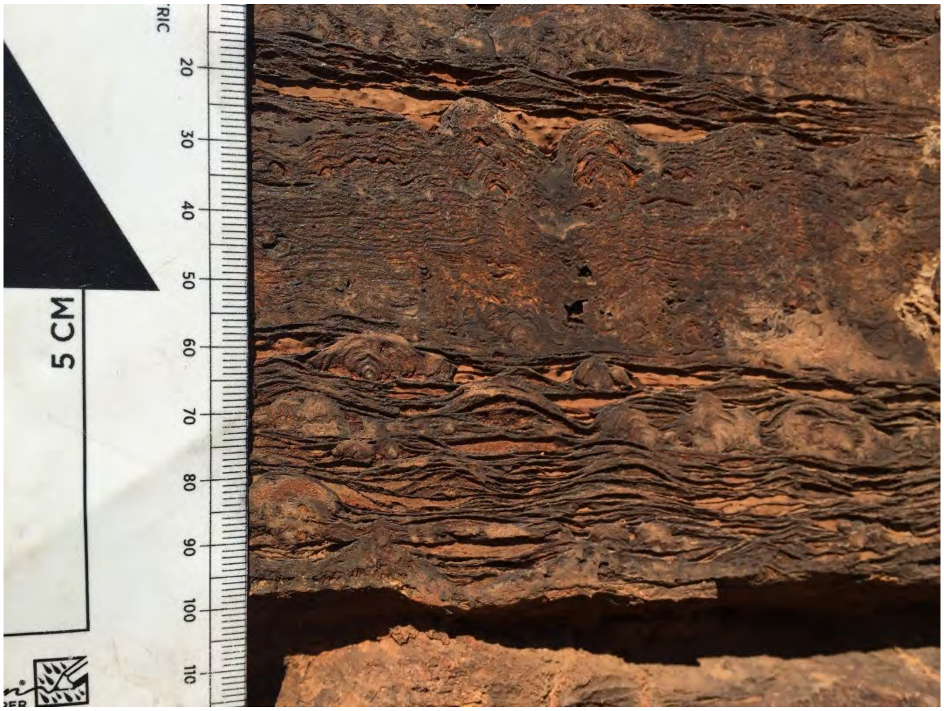
Some of the stromatolites are very large, as you can see in this image.

Marisol is examining the fine laminations of the Knossos microbial mats.

Giada and Shaunna pose with the incredible stromatolites at Knossos.

Knossos stromatolites

This image shows incredibly well-preserved climbing ripple cross-stratification on top of edgewise conglomerate. The depositional environment for the Tumbiana formation is still being debated.



Knossos stromatolites This image shows the complex interactions between sedimentary and microbial processes of the Tumbiana Formation. Microbial communities were in a constant battle with sedimentation. At times they were able to stabilize sediment and form stromatolites but often they were buried under it.

The above image shows evidence of a strong storm that disrupted and upended the microbial mats and caused the formation of this edgewise conglomerate.

The sunset at our campsite near Gallery Hill and Marble Bar.

Camping in the bush always required a communal effort! Here, Shaunna (at left) and others help with dinner preparation in the glow of a blazing campfire.

At Gallery Hill, we had the rare opportunity to observe petroglyphs created by the Bailgu or Palyku peoples. While the Pilbara is reputed to contain the world's largest concentration of Pleistocene petroglyphs, astonishingly little is known about them. Dating the carvings is challenging as no pigments were used.

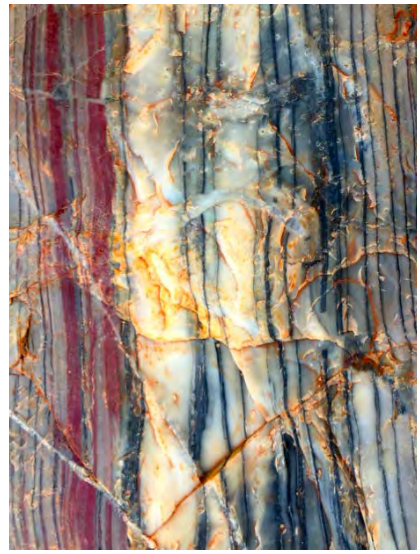
Petroglyphs of two females.

Petroglyph of an animal, possibly a kangaroo.

On the hike to Gallery Hill, we observed some unusual weathering of granite.

At Marble Bar, we visited the discovery site of purported 3.5 billion-year-old microfossils. The fossils were originally suggested to come from a shallow water environment, indicating that they may be a type of photosynthetic organism. However, as our guide Martin Van Kranendonk explained to us, they actually came from a hydrothermal chert vein in the paleo-subsurface we had to hike up this hill to get to (image below). This discovery called into question the biogenicity of the microfossils.

Dr. Martin Van Kranendonk is explaining the beautiful colors of the marble bar chert. The red material is the oldest, and it's cross cut by the younger blue and white veins injected by hydrothermal fluids.



A highlight of our stay at Marble Bar was getting to feed joey kangaroos! Here are Shaunna, Isabelle and Marisol getting to know one of the joeys.

The Strelley Pool stromatolites at the Trendall Locality were incredible in diversity and in form! These stromatolites are from 3.4 billion years ago, and three settings have been proposed for the layers of this locality: a shallow marine evaporative basin, an open marine environment, and a hydrothermal setting. The stromatolites pictured here are particularly fragile, and we had to be careful not to walk on them.

One of the big challenges when working with microbialites is interpreting the influences of environmental versus microbial processes in their preserved morphologies. Walking through the Shark Bay stromatolites and discussing morphology changes in the context of their environment was really helpful in thinking about their ancient counterparts.

For her Master's Thesis Marisol studied 2.52 billion year old microbialites from the Gamohaan Formation in South Africa. She was interested in the controls of microbialite morphology changes along a continuous and possibly varying depositional environment. The Astrobiology Grand Tour helped expand her experience with more traditional stromatolites and see how they varied with environments. The microbialites visited in this trip also expanded a wide age range. Their preservation decreased with increased age and Marisol was interested in how diagenesis affected the interpretations of their structures. Now at Arizona State University, Marisol is starting a doctorate program where she hopes to study how diagenesis affects the preservation of microorganisms in high temperature environments.

(Left-to-right) David Deamer, Bruce Damer, and Malcolm Walter at the Shaw River. David and Bruce gave our group a detailed lecture on some ideas regarding the origins of life.

These are some of the stromatolites at the “Buick Locality” in the ironically-named North Pole Dome region. The Buick Locality dates to 3.5 billion years ago, and Martin Van Kranendonk described these particular stromatolites as the oldest convincing evidence for life. Despite their age, the stromatolites at the Buick Locality are complex and diverse, indicating that life was well-established even at this early stage of Earth history. This early era, of course, lacked an ozone shield, and these stromatolites, like many at Shark Bay, were exposed to the surface at low tide. Giada has simulated how water with dissolved Fe^{2+}, which may have been abundant in the Archean ocean, can block UV radiation, protecting aqueous organisms from radiation damage. However, exposure to the surface implies that another UV-screening mechanism was in place at low tide. We saw the UV-screening pigment scytonemin at Shark Bay; scytonemin is synthesized by types of cyanobacteria, but it is not produced by anoxygenic photosynthesizers, which likely evolved first. There have been limited studies investigating the UV-tolerance of anoxygenic photosynthesizers (Pierson et al 1984). Giada’s research involves simulating the climatic and spectral effects of the organic haze that geochemical evidence suggests existed intermittently in the Archean. Thanks to inspiration from the stromatolites, Giada plans to examine in detail how an organic Archean haze could have acted as a UV shield and provided protection to surface and near-surface Archean organisms like the Buick Locality microbial mats.

Final Thoughts

We gained so much from our experience in Western Australia with the diverse group of scientists, educators, and hosts! We garnered a much fuller and richer understanding of how ancient rocks are studied and the difficulties of interpreting the Archean rock record in the correct context. However, seeing modern analogs to Archean life at Shark Bay and comparing them to the Archean fossils has elucidated how researchers use extant life to guide their understanding of early organisms. Those searching for life on other planets will undoubtedly make use of similar techniques, applying what we know about Earth life, its genesis and its evolution to other worlds. We look forward to utilizing the insights gained in the outback to our research at our home institutions!